ASIAEX Scattering Strength and Subbottom Geoacoustic Inversions

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Grant Number: N00014-01-1-0171
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LONG-TERM GOALS

The long-term goals of this work are to develop processing approaches that enable the estimation of both seafloor scattering strength and subbottom geoacoustic parameters from monostatic and bistatic scattering observations.

OBJECTIVES

The objectives of this research are to develop inversion procedures for the estimation of both seafloor scattering strength and subbottom geoacoustic parameters based on both forward propagation data and monostatic backscatter (reverberation) and to demonstrate their use in the analysis of data collected during the East China Sea component of ASIAEX.

APPROACH

Sophisticated modeling of seafloor scattering involves the incorporation of a large number of waveguide parameters in full-wave propagation models. When the waveguide parameters are known, substantial success has been achieved in using these models to predict reverberation observations from at-sea experiments. When some of the waveguide parameters are not known, various techniques have been developed to invert for or estimate these parameters with low frequency data (e.g. both simulated annealing (SA) and genetic algorithm (GA) approaches have been used quite successfully). The focus of this research is on the development of higher frequency inversion procedures for both forward propagation and monostatic backscatter (reverberation) data.

The East China Sea component of ASIAEX took place 29 May – 9 June 2001 primarily in 105 m deep water approximately 560 km ESE of Shanghai, P.R. China and 380 km NNW of Naha, Okinawa. Both acoustic propagation and scattering data were collected during the experiment over a broad range of frequencies (100 Hz – 20 kHz) as well as substantial environmental data (e.g. water column sound speed, current structure, wind speed, sea surface wave spectra, and surficial seafloor characteristics) [1].

The specific acoustic data collected by our group included both forward propagation (source tow) and monostatic backscatter (reverberation) data. The forward propagation data were recorded on a 16-element, 75 m aperture, autonomous vertical receive array. Radial source tow tracks were carried out in two frequency bands: (1) 95 Hz – 905 Hz (CW tonals at 95, 195, 295, 395, 805, 850, and 905 Hz)

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **ASIAEX Scattering Strength and Subbottom Geoacoustic Inversions**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Marine Physical Laboratory,,Scripps Institution of Oceanography,,La Jolla,,CA,92093**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long-term goals of this work are to develop processing approaches that enable the estimation of both seafloor scattering strength and subbottom geoacoustic parameters from monostatic and bistatic scattering observations.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

and (2) 1.6 – 4.4 kHz (CW tonals at 1.6, 2.4, 3.5, and 4.4 kHz). The monostatic backscatter data were collected at two center frequencies: (1) 850 Hz (small-aperture, 4-element source array with the data recorded on the 16-element VLA nearly collocated with the source) and (2) 3.5 kHz (using a 29-element, 78 m aperture source/receive array).

WORK COMPLETED

Geoacoustic inversion results have been completed for the low frequency source tow transmissions (195, 295, and 395 Hz) [3] and extended to include the mid-frequency transmissions (805, 850, and 905 Hz) [4].

RESULTS

The source tow tracks ran NW from the autonomous VLA. The geoacoustic model proposed for the experiment site is shown in Figure 1 and consists of a sediment layer over a basement half-space. The water depth in the source tow region is known to be approximately 105 m. The source tow data analyzed was collected on 7 June (Julian Day 158) 0313-0443 UTC.

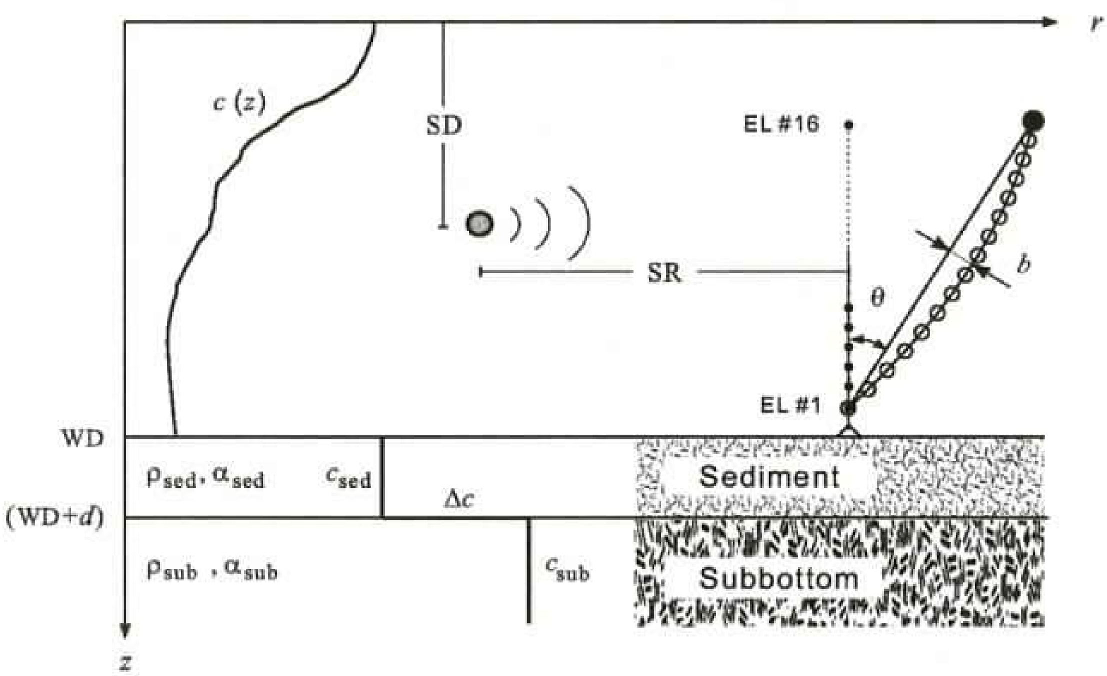

Figure 1. Geoacoustic model proposed for the experiment site consisting of a sediment layer over a basement half-space. The water depth in the source tow region is known to be approximately 105 m.

Although CTD's were taken at the VLA prior to and after the source tow, the water column sound speed structure in the experiment area was very dynamic. Figure 2 shows the first six eigenfunctions obtained from an EOF analysis of the CTD's collected during the experiment. Coefficients for the first three eigenfunctions were included in the inversion.

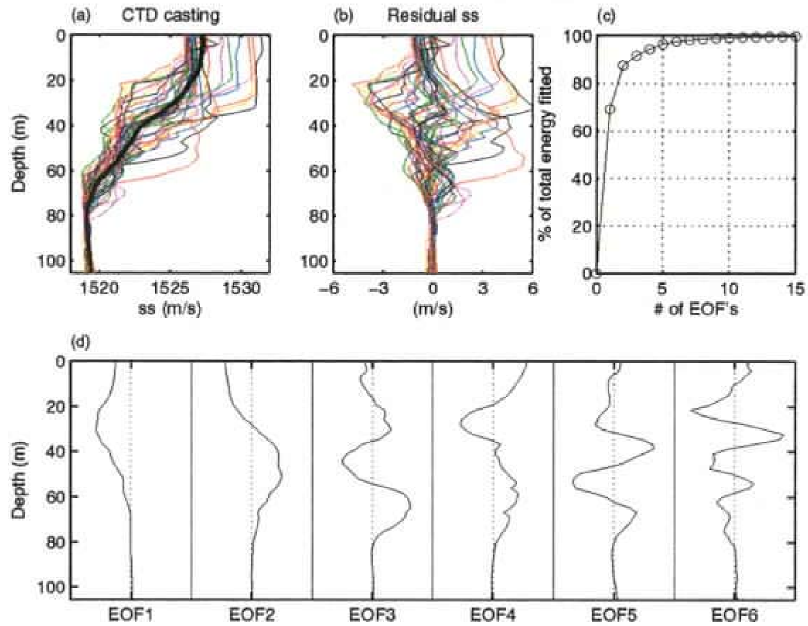

Figure 2. EOF analysis of the CTD's collected during the experiment. (a) Overplot of the CTD's (dark line is the mean sound speed profile). (b) Residuals about the mean profile. (c) Eigenvalue distribution. (d) First six eigenfunctions.

Using source tow tonal data at 195, 295, and 395 Hz and a range of 1.7 km, SAGA (Seismo-Acoustic Genetic Algorithm [2]) was used to estimate parameters of the geoacoustic model in Figure 1 based on a Bartlett matched field objective function. In addition to EOF coefficients characterizing the water column sound speed structure, other parameters estimated included source range and depth, water depth, and two parameters characterizing the array shape (tilt and bow). These and the estimated waveguide geoacoustic parameters are tabulated in Figure 3.

Parameter		$\text{SAGA}_{\text{best}}$	$\text{SAGA}_{\text{mean}} \pm \sigma$
SR	(m)	1714	1714 ± 16
SD	(m)	48.3	48.4 ± 0.2
WD	(m)	105.4	105.4 ± 0.6
Bow	(m)	1.3	1.3 ± 0.1
θ	(deg)	-6.02	-6.02 ± 0.08
c_{sed}	(m/s)	1585	1588 ± 7
Δc	(m/s)	74	43 ± 24
d	(m)	10	10 ± 3
α_{sed}	(dB/λ)	0.28	0.2 ± 0.1
ρ_{sed}	(dB/λ)	1.8	1.8 ± 0.2
EOF 1		6.3	6.1 ± 0.6
EOF 2		-2.2	-2.0 ± 0.6
EOF 3		-1.6	-1.7 ± 0.7

Figure 3. SAGA (Seismo-Acoustic Genetic Algorithm) parameter estimates from the source tow tonal data at 195, 295, and 395 Hz and a range of 1.7 km.

As an indication of the quality of the estimated geoacoustic parameters, Figure 4 shows Bartlett matched field ambiguity surfaces averaged across the three frequencies. The left panel corresponds to the same data used in the inversion when the source was at a range of 1.7 km. The right panel corresponds to data when the source was at a range of 2.8 km. Figure 5 extends this look across all ambiguity surfaces for source ranges between 1 and 4 km. The left panel is the time-evolving range surface (at the peak depths) and the right panel is the time-evolving depth surface (at the peak ranges). Excellent tracking of the source position is maintained.

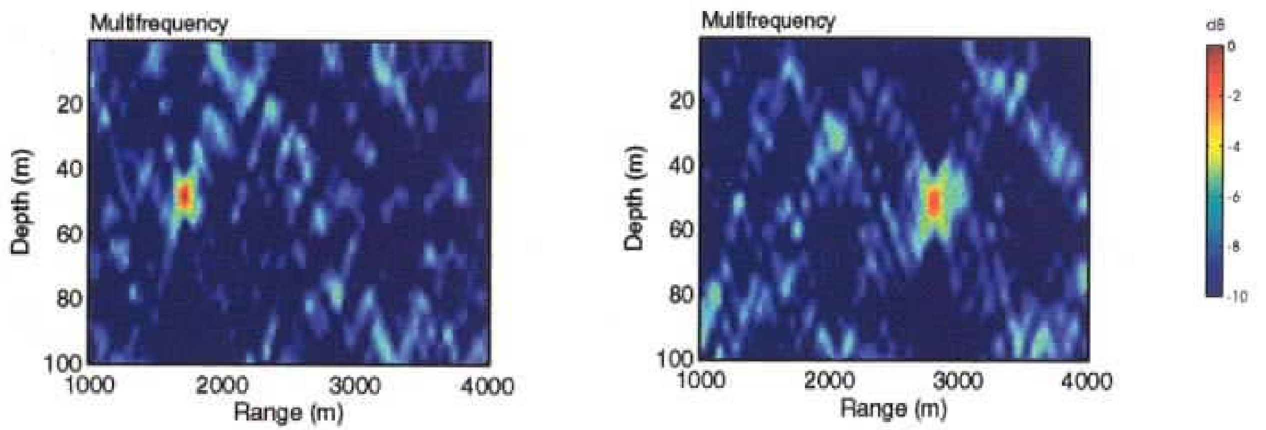

Figure 4. Bartlett matched field ambiguity surfaces for the source tow data averaged across three frequencies (195, 295, and 395 Hz). (a) Source range 1.7 km which corresponds to the same data used in the inversion. (b) Source range 2.8 km.

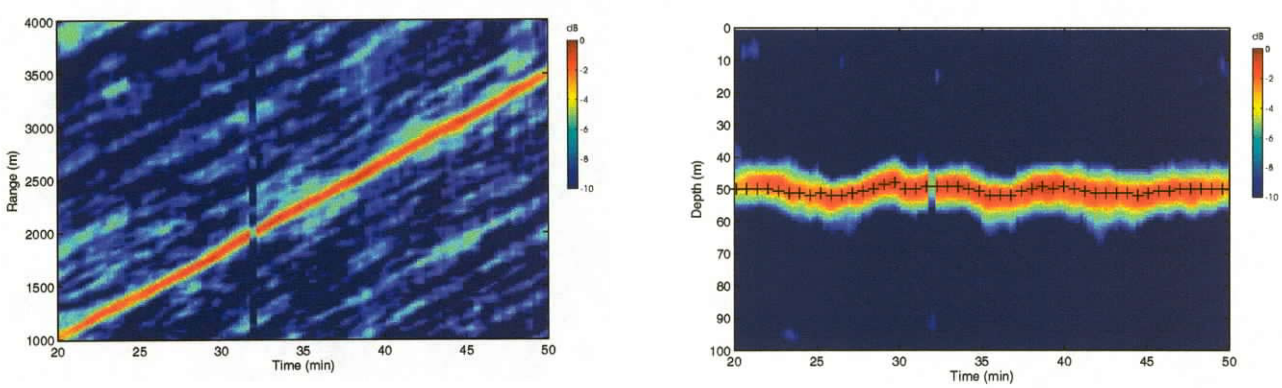

Figure 5. Bartlett matched field ambiguity surfaces for source ranges between 1 and 4 km. (a) Time-evolving range surface (at the peak depths). (b) Time-evolving depth surface (at the peak ranges). The "+" symbols indicate the true depths as measured by a depth sensor on the source.

IMPACT / APPLICATIONS

Geoacoustic inversion techniques are of general interest for the estimation of waveguide parameters thus facilitating system performance prediction in shallow water. Natural transition paths for these results will be SPAWAR (PMW-155) and NAVSEA (ASTO).

RELATED PROJECTS

This project is one of several sponsored by ONR Code 321OA to participate in the East China Sea component of the ASIAEX program.

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[2] P. Gerstoft, “SAGA User Manual 2.0: An Inversion Software Package,” SM-333, SACLANT Undersea Research Centre, La Spezia, Italy (1997) (SAGA Ver. 4.1 is available at http://www.mpl.ucsd.edu/people/gerstoft/saga/saga.html).

PUBLICATIONS

[3] C-F. Huang and W.S. Hodgkiss, "Matched field geoacoustic inversion of low frequency source tow data from the ASIAEX East China Sea experiment," IEEE J. Oceanic Engr. (2003). [submitted]

[4] C-F. Huang and W.S. Hodgkiss, "Mid-frequency geoacoustic inversion of source tow data from the ASIAEX East China Sea experiment," OCEANS 2003 (2003). [submitted]